Welcome!

The program will begin soon.

You will not hear audio until we begin.

1

Webinars

The Practical Aspects of CCS Project planning for the P&F Community

SPE International

2

Webinars

SPE Webinars are Sponsored by:

SPE

SPE Foundation

3

Webinars

Challenges Associated with Safe and Efficient Operation of Large Scale Multi Emitter CCUS Projects

Dale Erickson, PhD, Wood

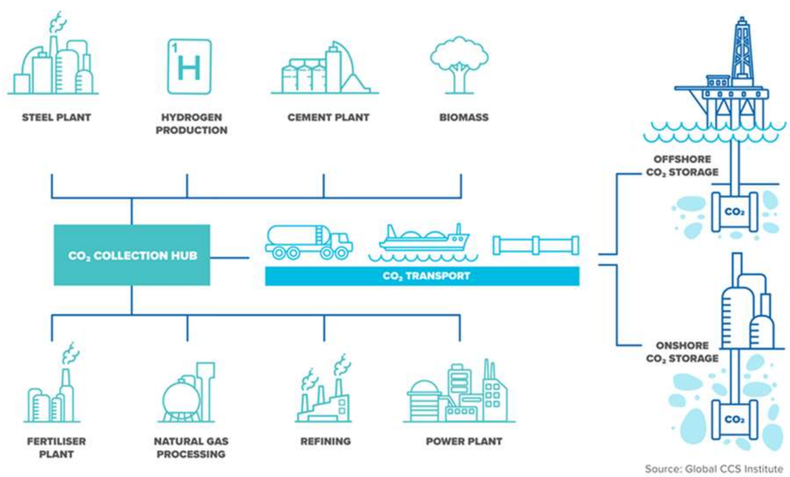
September 7th

4

Webinars

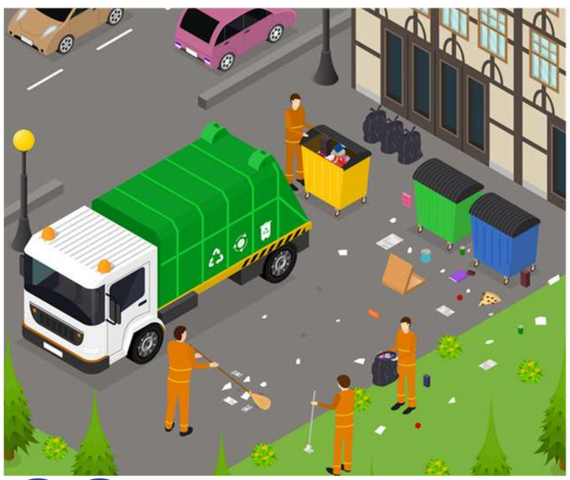
Safety Moment – Careful with Reverse Parking

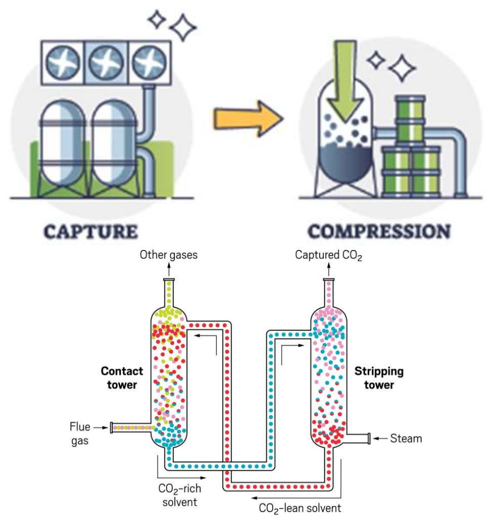
CCUS Networks



6

CO2 Biz will be like Garbage Collection – Will Often Collect Packets of Gas with Varying Quality

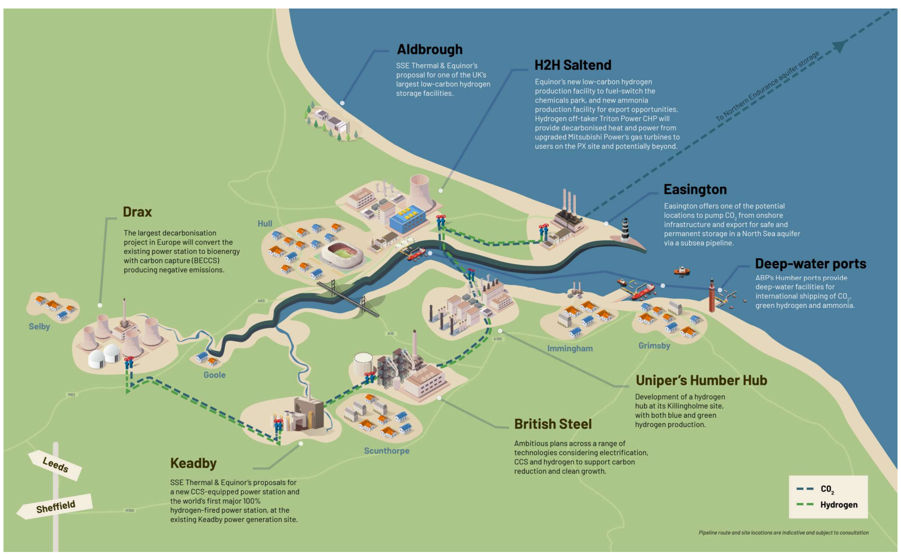




7

Example Project

Webinars



SPE International

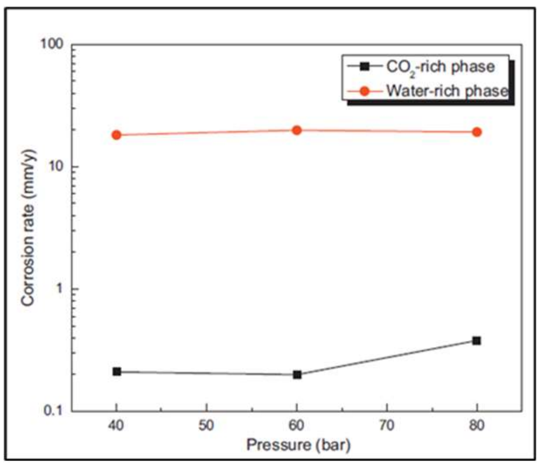
8

Custody Transfer

Custody Transfer takes place any time fluids are Passed from possession from one Party to Another

Custody Transfer is contract driven – contractual obligation between upstream and downstream in terms of flowrate and CO_2 Quality

Corrosion Slides

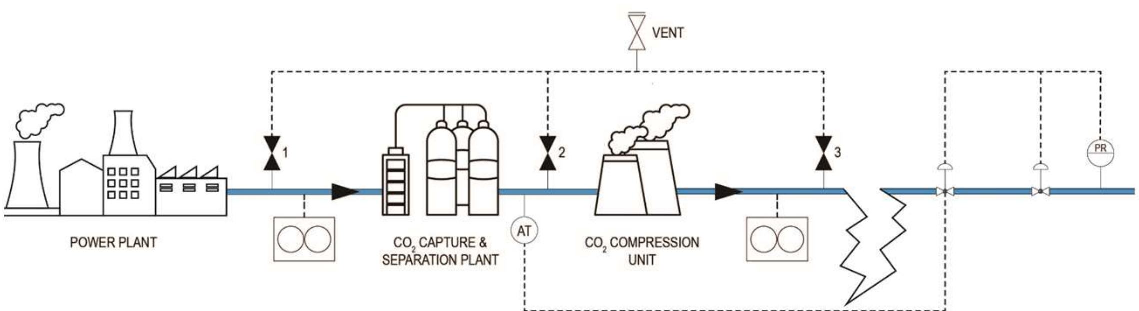


10

Venting/Blending Control

Carbon Capture and Compression Requires 30% More Energy – Thus CO2

Local Minimization of CO2 may not be Network Optimum when you have 30 emitters



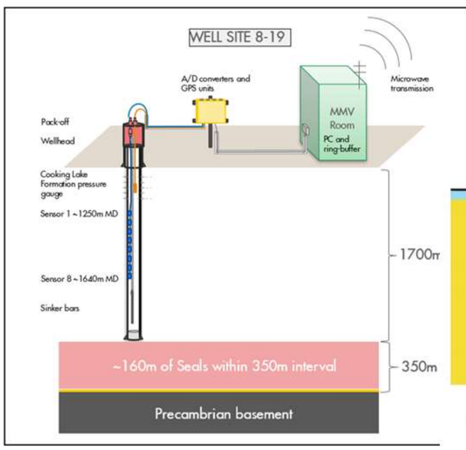
11

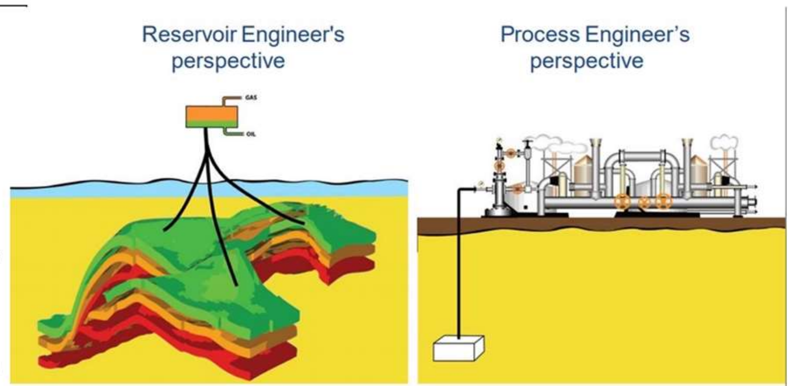
If Downstream Can't Take it Vent It

- Since CO_2 Capture is Expensive Energy Wise (30% additional energy)
- If Downstream Can't Take it – Vent it before Capture.

12

Injection Wells





Different experts have different perspectives – need to understand each other

13

CO_2 Network Balancing

- Need Each Emitter to Have Flowrate Control
- Balance Network when Capacity is Limited
- Some Emitters May Be Willing to Pay More to Get Rid of their CO_2
- Network Floats on the Worst Wells – Optimum Network Operating Pressure (less compression)
- Need Whole Network View

14

Measuring the Impurities

Webinars

HCl	0 - 50	mg/Nm3, trocken
CO	0 - 1 / 12	Vol%, trocken
NO	0 - 400 / 4000	mg/Nm3, trocken
NO2	0 - 200 / 400	mg/Nm3, trocken
SO2	0 - 1000 / 15000	mg/Nm3, trocken
CO2	0 - 90	Vol%, trocken
H2O	0 - 40	Vol%
O2	0 - 10 / 25	Vol%, trocken

SPE International

15

Quality Issues

- Once Downstream Takes Possession of the Gas – it is downstream' s problem
- A 1 in 1000-year Failure in Dehydration Means for 30 emitters – one failure over systems lifetime.
- Keep Bad Gas from Entering Downstream Network
- However, if bad gas enters Network have to deal with it.
- So Downstream Quality Requirement's Starting at Reservoir – have to flow back upstream – **Sum of all constraints**

16

Example of Blend/Venting System

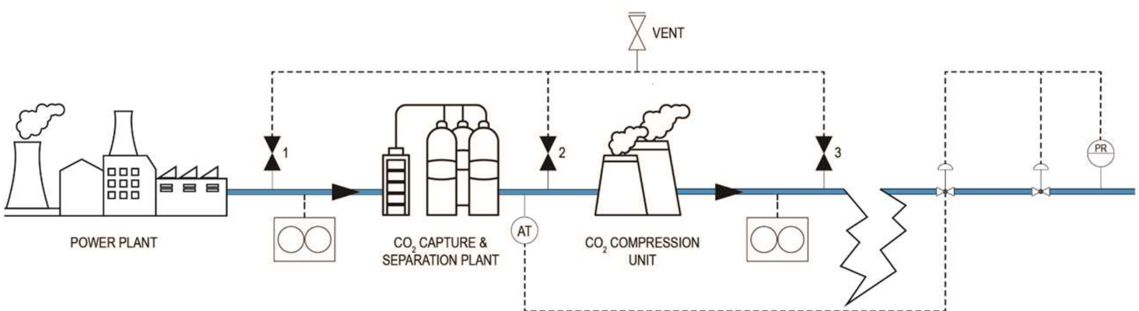
		Power Plant	Steel Plant	Cement Plant	LNG	H2 Production		Export
BMS TO ESD		NORMAL	NORMAL	NORMAL	TRIP	NORMAL		NORMAL
Plant Status		NORMAL	NORMAL	NORMAL	CLOSED	NORMAL		NORMAL
Chromat Status		HEALTHY	Calibration	HEALTHY	Offline	HEALTHY		HEALTHY
Time Updated		10:30:08	10:29:14	10:30:38	10:27:08	10:30:56		10:31:23
CO2	%	98.30	97.50	98.80	97.50	97.20		97.86
N2	%	1.26	1.58	0.01	0.68	0.70		0.85
CH4	%	0.05	0.30	0.55	1.50	0.72		0.62
CO	%	0.12	0.25	0.33	0.20	0.25		0.23
Ar	%	0.25	0.33	0.28	0.05	0.33		0.25
H2	%	0.00	0.02	0.01	0.05	0.78		0.17
H2S	ppm	0.50	21.20	10.50	0.00	0.00		1.20
H2O	ppm	54.00	36.00	51.00	1400.00	24.50		113.10
O2	ppm	9.50	6.20	3.20	1.50	2.20		4.52
SOX	ppm	7.20	24.00	20.40	0.30	1.50		10.68
NOX	ppm	13.20	19.80	24.60	1.80	0.84		12.05
Flowrate	tonnes/hr	977.00	145.00	266.00	544.00	177.00		2109.00

17

Venting/Blending Control

Carbon Capture and Compression Requires 30% More Energy – Thus CO2

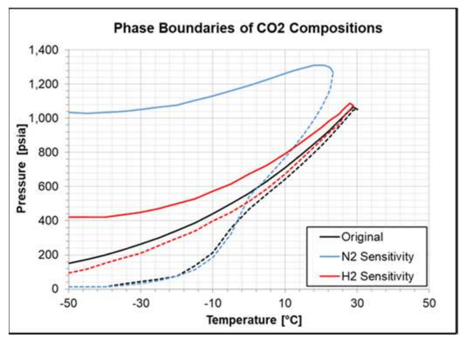
Local Minimization of CO2 may not be Network Optimum when you have 30 emitters



18

Impurities and Phase Boundary

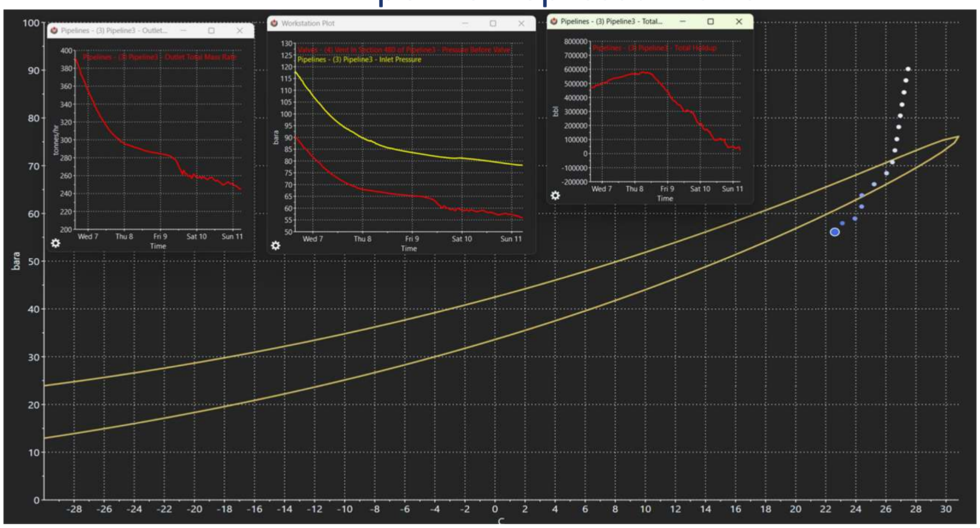
Webinars



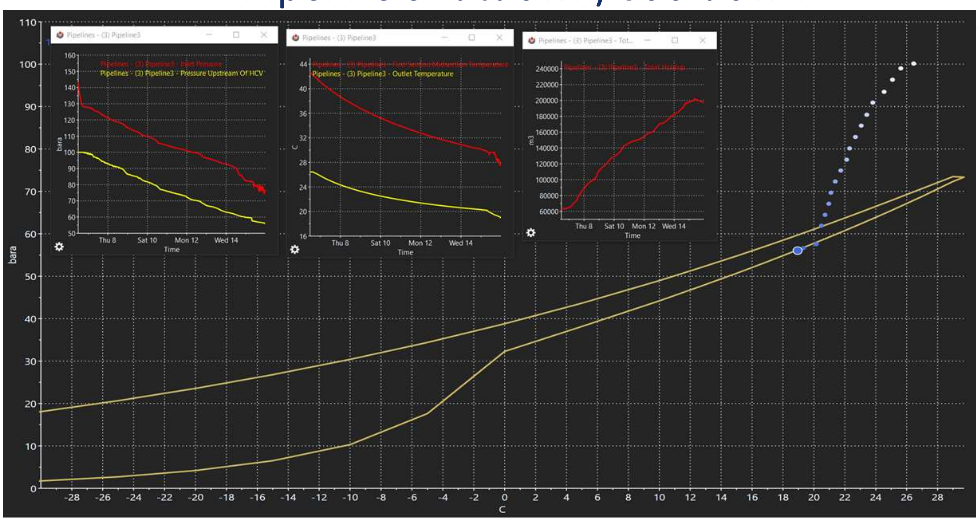
SPE International

19

Pipeline Depressurization



Pipeline Shutdown/Cooldown

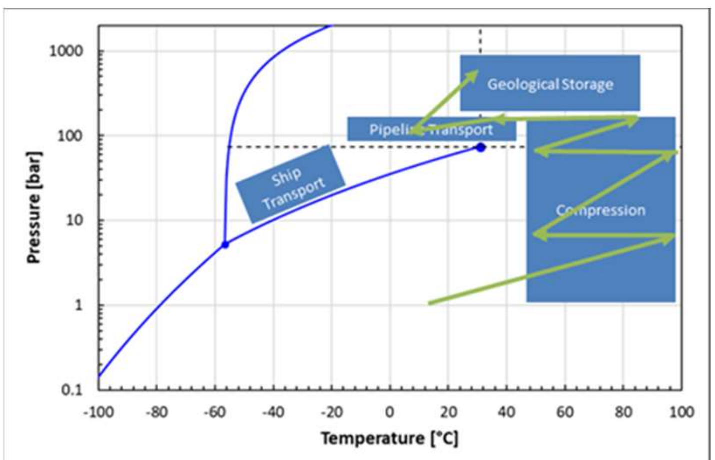


Webinars

SPE International

21

Pumping vs Compression



22

Downstream Venting Issues

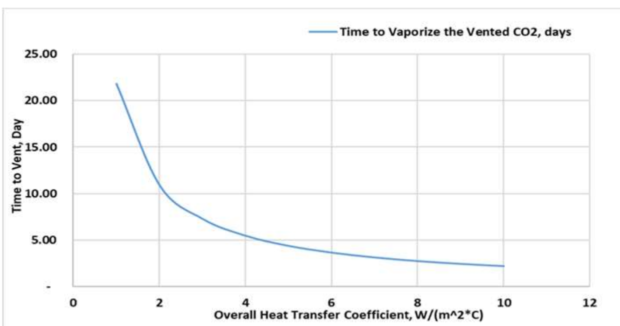
- Assumption:
  - The system is at ambient temperature.
  - To vent, it is required to vaporize the CO_2 from liquid to gas. No Driving Force for the Transport of Liquid
  - CO_2 vaporization is heat transfer limited.

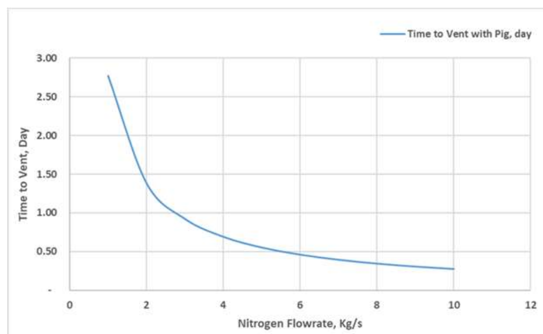
Pipe Diameter	30	in
Pipe Diameter (SI)	0.762	m
Pipe Cross-section Area	0.456	m^2
Pipe Length	15	Km
Pipe Length (SI)	15,000.00	m
Pipe Volume	6,840.55	m^3
Outside Surface Area of Pipe	35,908.40	m^2
Density of Nitrogen at 30 bar	35	Kg/m^3
Density of Liquid CO2 at 0 C	860	Kg/m^3
Mass of CO2	5,882,873.83	kg
heat of vaporization (at 0 C) of CO2	230.5	kJ/kg
Total Required Heat to Vaporize CO2 in the Pipe	1,356,002,418.35	kj
Nitrogen Flowrate	5	Kg/s
Delta T	20	C

23

Venting vs N2 Pigging

Webinars



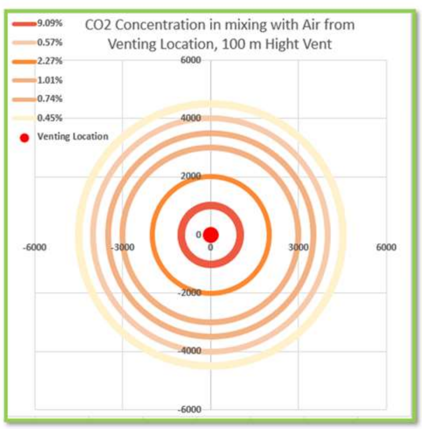


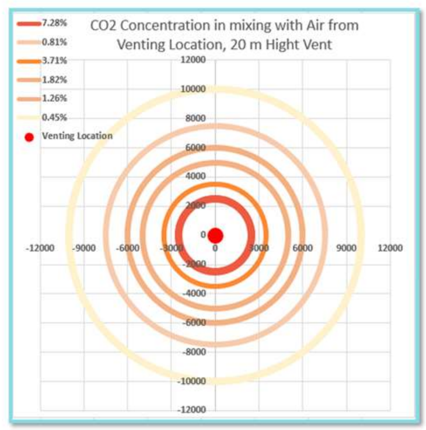
SPE International

24

What do you do with 6 Million Kg of Co2

Webinars





SPE International

25

Where to Put the Vents

- CO_2 Will Travel Downhill
- For Dewburry Accident with 3 million kg – CO_2 Traveled 30 km in one direction – impacted by the wind.
- Pipeline Routing will be major concern

26

Conclusion

- Operation of CO2 Network will be complex operation which will require online monitoring/control.
- Operational aspects must be considered during the design and location of the pipeline network.
- In venting temperature is an issue – don't insulate – it will only increase blowdown time

Classifying and Categorizing Storable Quantities using SPE's CO_2 Storage Resources Management System

Presented as part of the webinar:

The Practical Aspects of CCS Project Planning for the P&F Community

Scott M. Frailey, PhD, PE
Illinois State Geological Survey
University of Illinois @ Urbana-Champaign

September 7, 2023

Prairie Research Institute
UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN
Illinois State Geological Survey

28

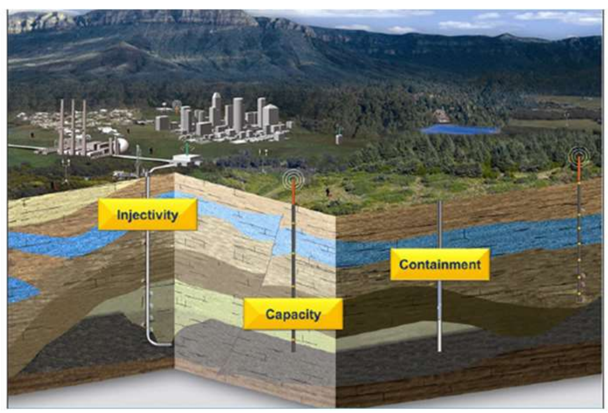
The Content of This Presentation

- The slides presented here were developed by the presenter for this presentation and from previous presentations.
- Application of resource management systems are subjective; therefore, the opinions shared here are those of the presenter and not necessarily SPE, CCUS Technical Section, or the CO_2 Storage Resources Committee.

Storage Resources Management System (SRMS) Outline

Webinars

- Background
- SRMS Structure:
  - Classification
  - Categorization
- Example Applications
- Summary



30

30

Background
SRMS: Purpose and Intended Users

- Intended users: financial, corporate, government organizations involved **commercial** CO_2 storage projects
- Purpose: to provide
  - **common terminology** and **clear definitions** needed to classify storable quantities in the context of defined projects intended to be matured to commerciality.
  - context for investment and performance tracking
- Applicable to
  - regional or basin resource assessments via a **notional** storage project
  - Brine aquifers (S_w = 100%) and depleted oil and gas reservoirs
  - ***Note***: *2024 SRMS expected to include CO_2 EOR.*

2017 SRMS

Background:
SRMS Development

- CO_2 Storage Resources Committee (CSRC) member selection
  - PRMS and/or CO_2 storage expertise
  - Represent seven professional societies
- Petroleum Resources Management System (PRMS)
  - Seed Document
  - Time tested and applied system
  - Supported by financiers, security exchanges, and governments (world)
- Fall 2017: SRMS Published by SPE
- Summer 2021: Sponsoring Societies
  - SPEE, AAPG, EAGE, SEG, SPWLA, WPC
- February 2022: First published commercial usage:
  - Santos booked, with external auditors:
    - 100 Mt of CO_2 Capacity, at 1.7 Mt/yr
    - 1.2-1.6 B$
- June 2022: SRMS-Guidelines published by SPE
- Summer 2024: Update to SRMS

32

32

Storable Quantities

- Quantities of CO_2 (mass or standard volume) that can be stored as part of an estimated pore volume of a geologic formation that is accessible to CO_2 via a storage project sometime in the future
- Requires containment
- Directly related to project specifications

Definition in 2017 SRMS

- For a geologic formation to have storable quantities, it must have
  - pore volume accessible to CO_2 (quantity and sustained injection rate commensurate with the **project specifications**) and
  - containment (e.g., existing wellbore and caprock integrity) of the **Stored** CO_2 over a time period established by the **project specifications**

2022 SRMS Guidelines

Project Specifications

Webinars

Commercial Projects

- Development plan with details to mature the project to active, commercial storage
- Standalone project
  - CO_2 storage as a business with expenses and income directly related to the storage of CO_2
- Integrated project
  - CO_2 storage is integrated into a project with other revenue generating product, e.g. an industrial plant to power generating plant
  - CO_2 storage part may be expense only or generate revenue and expenses

Notional Projects

- Development plan to scope resource to provide general understanding of the storable quantities
- Exclusively used for very immature projects
- Primarily defines the **area**, **geologic formation** (i.e. thickness), and **containment**
- May lead to
  - Region for site *screening*
  - Area for site *selection*
  - Location to drill characterization well
  - Identification of existing well to characterize

SPE International

2022 SRMS Guidelines, Section 2.1.4.4

34

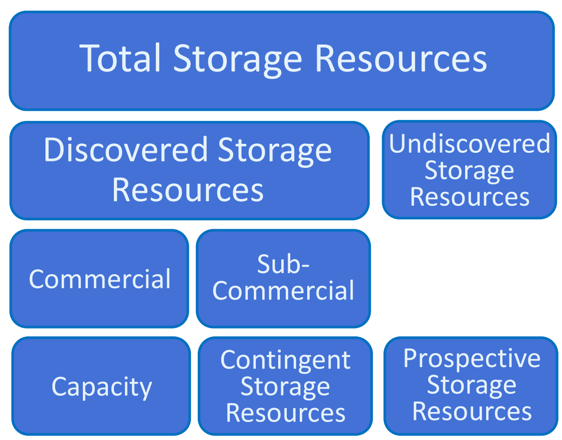
34

SRMS Structure: Classification of Storable Quantities

Based on Project Maturation

- **Discovered** (DSR) vs. **Undiscovered** (USR)
  - storable quantities for which one or more wells established through testing, sampling, and/or logging the existence of a quantities sufficient to meet project requirements.
- **Commercial** vs. **Sub-commercial**
  - essential social, environmental, and economic conditions are met, including political, legal, regulatory, and contractual conditions.
  - degree of management commitment is such that storage project is expected to be developed and placed on injection within a reasonable timeframe.

Specific to Defined or Notional Project



**Not shown, Inaccessible SR, which has no project.*
Total SR includes Inaccessible SR: Discovered and Undiscovered ISR

35

Classification: **Prospective** Storage Resources (*Undiscovered* Storage Resources)

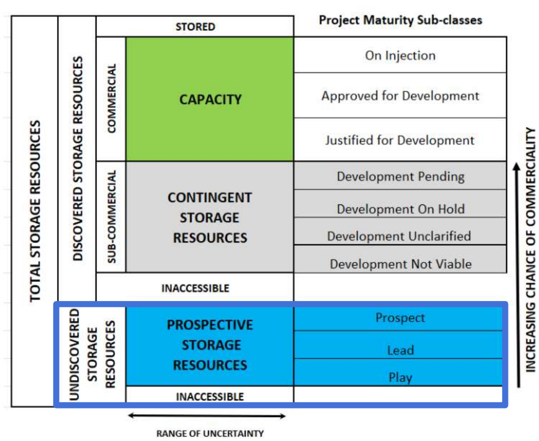
Webinars

Well does not exist or not assessed

Increasing Chance of Commerciality

- Play: A project associated with a prospective trend of potential prospects, but that requires more data acquisition and/or evaluation to define specific leads or prospects.
- Lead: A project associated with undiscovered storable quantities that is currently poorly defined and requires more data acquisition and/or evaluation to be classified as a prospect.
- Prospect: A project associated w/ undiscovered storable quantities sufficiently defined to represent a viable drilling target
- PSR maturation process "ends" with a drilling prospect or existing well identified to assess

SPE International



Revised figure 2.1 in errata of 2017 SRMS

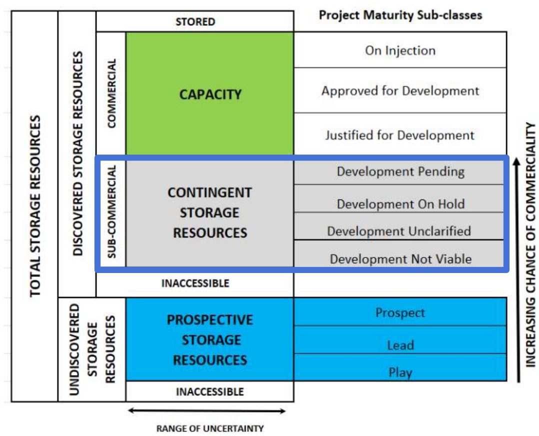
36

Classification: **Contingent** Storage Resources
(*Discovered, Sub-Commercial* Storage Resources)

Increasing Chance of Commerciality

Well exists and assessed or being assed

- Development Not Viable: Discovered storable quantities for which there are no current plans to develop or to acquire additional data at the time as a result of limited storage potential.
- Development Unclarified: Discovered storable quantities where **project** activities are under evaluation and where justification as a commercial development is unknown on the basis of available information.
- Development On Hold: Discovered storable quantities where **project** activities are on hold and/or where justification as a commercial development may be subject to significant delay
- Development Pending: Discovered storable quantities where **project** activities are ongoing to justify commercial development in the foreseeable future.
- CSR maturation process "ends" with commercial proposal to management



37

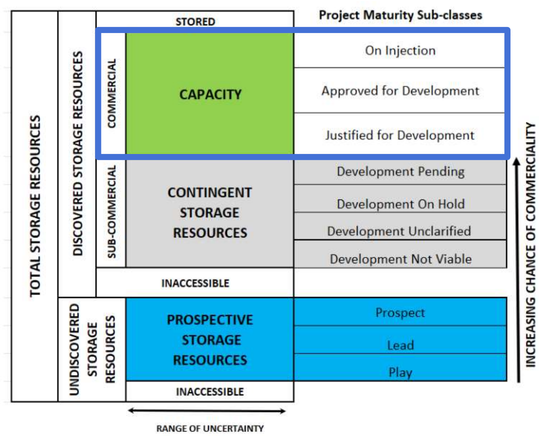
Classification: **Capacity**

(*Discovered*, *Commercial* Storage Resources)

Increasing Chance of Commerciality

No Contingencies Exist

- **Justified for Development:** Implementation of the development project is justified on the basis of reasonable forecast commercial conditions at the time of reporting, and there are ***reasonable expectations*** that all necessary approvals/contracts will be obtained.
- **Approved for Development:** *All* necessary approvals have been ***obtained***, capital funds have been committed, and implementation of the development project is underway.
- **On Injection:** The development project is currently injecting and storing CO_2.



38

SRMS Structure: Categorization of Storable Quantities

- Categorizations
  - **Low** estimate
    - High probability
    - P_{90}
  - **Best** estimate
    - Most-likely (median)
    - P_{50}
  - **High** (low probability) estimate
    - Low probability
    - P_{10}

- Categorization:
  - Indicative of certainty in storable quantities
  - Based on project's specifications, but **NOT** the project's maturity

← Project Maturity ←

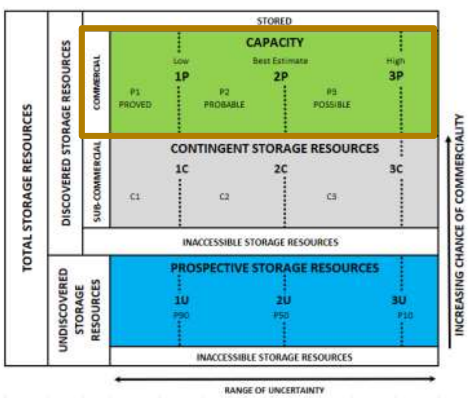
Geologic Certainty ↑

Category	Probability	Capacity	Contingent	Prospective
Low Estimate	P_{90}	1P	1C	1U
Best Estimate	P_{50}	2P	2C	2U
High Estimate	P_{10}	3P	3C	3U

Capacity, Low Estimate: highest geologic certainty and highest project maturity
Prospective, High Estimate: Lowest geologic certainty and lowest project maturity

Categorization: Certainty in Storable Quantities

Webinars



Ex: P1 + P2 + P3 = 3P

- Proved (P1): **Proved Capacity** (P_{90}) is the quantity of storage that, by analysis of geoscience and engineering data, can be estimated with reasonable certainty to be commercially used for storage, from a given date forward, from known geologic formations and under defined economic conditions, operating methods, and government regulations.
- Probable (P2): **Probable Capacity** (P_{50}) is the additional Capacity that analysis of geoscience and engineering data indicate are less likely to be used for storage than Proved Capacity, but more certain to be used for storage than Possible Capacity
- Possible (P3): **Possible Capacity** (P_{10}) is the additional Capacity that analysis of geoscience and engineering data suggest are less likely to be stored than Probable Capacity.

SPE International

Note: All Capacity categories are subordinate to Capacity requirements.
Examples: Management commitment exists; permit allows development; capital committed

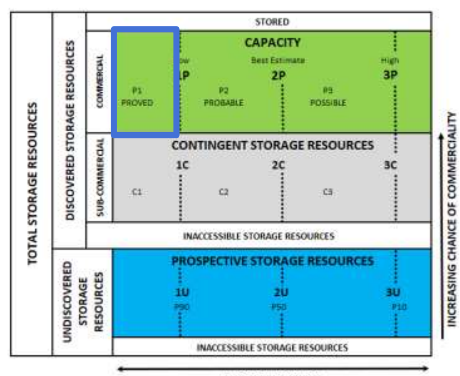
40

40

Proved Capacity's Operational Status

Webinars

- Proved, Developed, Injecting: Developed Injecting Capacity is expected to be stored from completion intervals that are open and injecting at the time of the estimate.
- Proved, Developed, Non-injecting: Developed Non-injecting Capacity includes shut-in and behind-pipe Capacity.
- Proved, Undeveloped: Undeveloped Capacity is the quantity expected to be stored through future investments.



SPE International

*Note: All Status are subordinate to **all** Capacity requirements.*
Examples: Management commitment exists; permit allows development; capital committed

41

SRMS Applications Example

PROJECT MATURATION: FROM REGIONAL STUDY TO ACTIVE INJECTION

42

42

Assumptions Common to the Examples

- Thick, pervasive, basal sandstone (single geologic formation)
- Containment:
  - Wellbore: Few wellbore penetrations (No known minerals)
  - Geologic: Extensive, thick clay-rich shale caprock with minimal faulting
- Depth
  - Maximum: cementation lower porosity and permeability
  - Minimum: liquid-like CO_2 density; fresh water

43

43

Regional Assessment: Notional Project

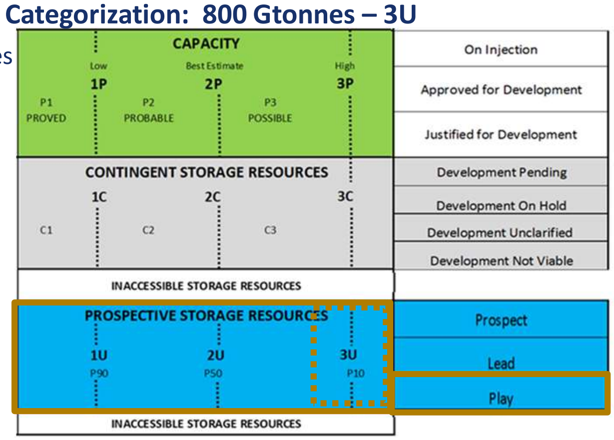
Webinars

- Purpose: storage potential
- Notional project:
  - Total regional emissions from stationary sources
  - Fully developed infrastructure
- Volumetric approach
  - Pore volume with storage efficiency
  - Single value (deterministic)
- Boundaries:
  - Perimeter: State lines
- Outcome:
  - General geographical area for a site
  - Estimate: 800 Gtonnes (high estimate)

SPE International

Classification: Prospective Storage Resources–Play

Categorization: 800 Gtonnes – 3U



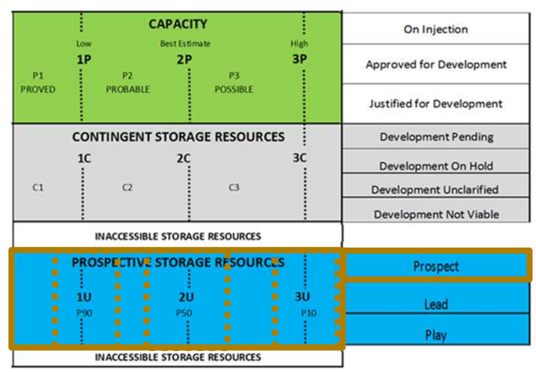
44

Regional Assessment: Notional Project Use of New Data and New Analysis

Webinars

- Objective: storage potential, site screening
- Volumetric, GIS approach
  - Efficiency: displacement, and geologic attributes
  - High, medium, low values (E= 1, 2, 4%)
- Boundaries:
  - Perimeter: State Lines
- Outcome:
  - General Geographical area for a site
  - Storing on regional dip
  - Estimate: 25, 50, 100 Gtonnes

Classification: Prospective Storage Resources – Prospect
Categorization: 25 Gt – 1U; 50 Gt – 2U; 100 Gt – 3U



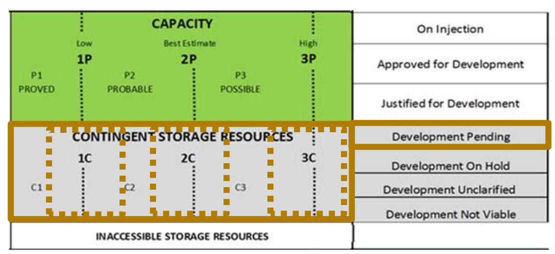
SPE International

45

Site Selected, Well Drilled, Well Assessed, Awaiting Management Commitment

Webinars

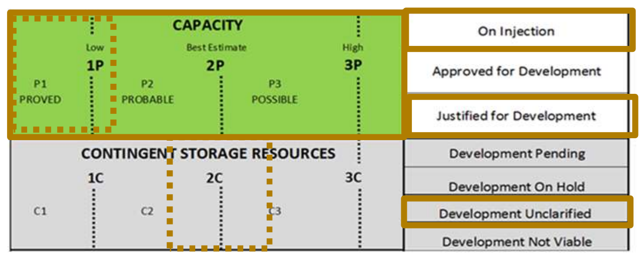
- Purpose: assess storage site single well injection and CO_2 emitted
- Storage Project Status (at time of assessment)
  - Site CO_2 emissions: 3,000 tpd
  - Capture facility (planned): 1,000 tpd,
  - <u>Management commitment NOT finalized 25 yr life</u>
- Deterministic-scenario approach *(2017 SRMS, p 13, sect 2.2.2)*
- Simulation: 8,000 tpd, well's max injection rate
- Boundaries: Storage rights and real estate ownership



Project	Class	Subclass	Comment	Stor Quantity	Category	Comment
Facility	**Contingent SR**	Development Pending	No Management commitment	9 Mt (1,000 tpd)	**1C**	Small facility
Site	**Contingent SR**	Development Pending	No Management commitment	30 Mt (3,000 tpd)	**2C**	Total site emissions
Well	**Contingent SR**	Development Pending	No management commitment	70 Mt (8,000 tpd)	**3C**	High estimate based on well

Active Injection:
Defined, Management Approved Project

- Purpose: Assess active project(s)
- Final Project
  – Infrastructure purchased: 1,000 tpd
  – Management commitment: 12 years
  – Permits and contracts issued/completed
- Planned Project Expansion
  – Management commitment: 1,000 tpd (incremental)
  – Reasonable expectation of permit



Project	Class	Subclass	Comment	Stor Quanty	Category	Comment
Final	Capacity	On Injection	Management commitment	4 Mt	Proved Developed Injecting, 1P	Active injection, equip. available
Planned	Capacity	Justified for Development	Management commitment; Permit expected	8 Mt	Proved Undeveloped, 1P	Permit required
Site	Contingent SR	Development Unclarified	No management commitment	58 Mt	2C	Best estimate

47

Summary of SRMS Applications Examples

- Classification: certainty in project
- Categorization: certainty in storable quantities
- SRMS intended use is in the context of storage projects
  - Active project specifications directly influences storable quantities
  - Notional project specifications acceptable for large scale resource assessments
- Storable quantities requires containment
- Prospective Storage Resources
  - no well available for assessment
- Contingent Storage Resources
  - well assessed and expected to meet project goals, but contingencies exist
- Capacity
  - solely for commercial/ economic projects
  - Reasonable expectation (minimum) that all permits/contracts obtained
  - Essential social and environmental project conditions met
- Classification and Categorization of storable quantities are subjective

48

48

SRMS Usage: Expected Outcomes

Webinars

- Provides guidelines for developing commercial storage projects
- Gives standardized terminology and definitions in commercial contracts similar to other subsurface commodity industries
- Assessors and stakeholders have a methodology to follow to make comparisons between projects
- System that relates project certainty and geologic certainty to storable quantities estimate

SPE International

49

49

Acknowledgements

- Society of Petroleum Engineers' members are leading and organizing the SRMS guidelines development with support of SPE staff. SPE is the largest individual-member organization serving managers, engineers, scientists and other professionals worldwide in the upstream segment of the oil and gas industry.
- Sponsored by American Association of Petroleum Geologists, European Association of Geoscientists and Engineers, Society of Exploration Geophysicists, Society of Petroleum Evaluation Engineers, Society of Petrophysics and Well Log Analysts, and World Petroleum Council
- Recommended by US Department of Energy

50

50

References

- "The CO_2 storage resources management system (SRMS): toward a common approach to classifying, categorizing, and quantifying storage resources", Scott M. Frailey, George J. Koperna, Owain Tucker, 14th International Conference on Greenhouse Gas Control Technologies (GHGT-14), October 21-15, 2018, Australia
- "The genesis of the CO_2 storage resource management system (SRMS)", Scott M. Frailey, Owain Tucker, George J. Koperna, 2016, 13th International Conference on Greenhouse Gas Technologies (GHGT-13) Proceedings. Energy Procedia 114: 4262-4269.
- https://www.spe.org/en/industry/co2-storage-resources-management-system/
- https://www.netl.doe.gov/sites/default/files/2018-10/BPM-SiteScreening.pdf

References

- "How to discover a storage resource: following the principles of the SPE-SRMS what is required to classify as storage resources as 'discovered' Lesley R Seldon, Owain Tucker, Sylvain Thibeau, Jacobo Canal Vila, Franco Masserano, 14th Intl Conf on Greenhouse Gas Control Technologies (GHGT-14) Proceedings, October 21-15, 2018, Australia